

Claims

What is claimed is:

1. A valve-operating lever comprising:
a valve arm including a first aperture defining a valve arm engagement portion;
5 a connector member;
a first stop cooperating with the connector member to at least partially define a first engagement portion, the valve arm engagement portion engaging the first engagement portion; and
a second stop positioned such that the valve arm is sandwiched between the first
10 stop and the second stop.
2. The valve-operating lever of claim 1, wherein the first aperture is substantially circular.
- 15 3. The valve-operating lever of claim 1, wherein the connector member includes a cylindrical tube.
4. The valve-operating lever of claim 1, wherein the first stop includes a first reduced-diameter portion that defines a first shoulder.
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5. The valve-operating lever of claim 1, wherein the valve arm defines a valve arm thickness and wherein the first engagement portion defines an axial length that is at least as great as the valve arm thickness.
- 25 6. The valve-operating lever of claim 1, wherein the valve arm is formed from a stamped metal.

7. The valve-operating lever of claim 1, wherein at least one of the valve arm engagement portion and the first engagement portion includes knurls.

5 8. The valve-operating lever of claim 1, wherein the first aperture includes a non-circular region, and the connector member includes a non-circular region that engages the non-circular region of the first aperture.

9. The valve-operating lever of claim 1, further comprising a lever arm
10 including a second aperture defining a lever arm engagement portion.

10. The valve-operating lever of claim 9, wherein the lever arm includes a follower surface adapted to engage a cam surface.

15 11. The valve-operating lever of claim 10, wherein the valve arm includes a valve actuating portion adapted to actuate a valve in response to movement of the lever arm.

12. The valve-operating lever of claim 1, wherein the first stop is integrally
20 formed as part of the connector member.

13. The valve-operating lever of claim 12, wherein the second stop is integrally formed as part of the connector member.

25 14. The valve-operating lever of claim 13, wherein the first stop and the second stop overlay a portion of the valve arm.

15. The valve-operating lever of claim 13, wherein the connector member includes a third stop, the connector member and the third stop cooperating to define a second engagement portion.

5 16. The valve-operating lever of claim 15, wherein the third stop is integrally formed as part of the connector member.

17. The valve-operating lever of claim 15, wherein the third stop includes a second reduced-diameter portion that defines a second shoulder.

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18. The valve-operating lever of claim 15, wherein a second portion of the connector member overlays a portion of the lever arm adjacent the second aperture, and the lever arm engagement portion engages the second engagement portion.

15 19. The valve-operating lever of claim 15, wherein at least one of the lever arm engagement portion and the second engagement portion includes a portion having knurls.

20 20. The valve-operating lever of claim 15, wherein the second aperture includes a non-circular region, and the second engagement portion includes a non-circular region that engages the non-circular region of the second aperture.

21. The valve-operating lever of claim 15, wherein the lever arm defines a lever arm thickness, and the second engagement portion defines an axial length that is at
25 least as great as the lever arm thickness.

22. A direct lever system for an engine, the system comprising:
- a cylinder bore, the cylinder bore having an outer end;
 - a cam assembly having at least one cam surface and an axis inward of the outer end of the cylinder bore;
 - 5 two valves having opened and closed positions;
 - two valve stems, each valve stem attached to one of the two valves;
 - a cylinder head substantially enclosing the outer end, the valves being seated in the cylinder head; and
 - two pivotably mounted valve-operating levers, at least one of the valve-operating
 - 10 levers including,
 - a connector member having a lever arm end and a valve arm end, the connector member defining a pivot axis about which the valve-operating lever pivots;
 - a lever arm including an aperture, a portion of the connector member engaging at least a portion of the lever arm adjacent the aperture to fixedly attach the
 - 15 lever arm to the connector member, the lever arm having a cam follower surface in contact with the at least one cam surface; and
 - a valve arm including an aperture, a portion of the connector member engaging at least a portion of the valve arm adjacent the aperture to fixedly attach the valve arm to the connector member.

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23. The system of claim 22, wherein the lever arm aperture and the valve arm aperture are substantially circular.

24. The system of claim 22, wherein the valve arm is formed from a stamped

25 metal.

25. The system of claim 22, wherein the connector member valve arm end includes a first stop.

5 26. The system of claim 25, wherein the first stop includes a first shoulder defined by a first reduced-diameter portion.

27. The system of claim 25, wherein the valve arm defines a valve arm thickness and wherein the first reduced-diameter portion defines a first axial length that is
10 at least as great as the valve arm thickness.

28. The system of claim 22, wherein the connector member valve arm end includes a first stop integrally-formed as one piece with the connector member valve arm end.

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29. The system of claim 22, wherein the connector member includes a first stop defined by a first swage.

30. The system of claim 29, wherein the connector member includes a second
20 stop defined by a second swage.

31. The system of claim 22, wherein at least one of the lever arm aperture and the lever arm end of the connector member includes knurls.

25 32. The system of claim 22, wherein at least one of the valve arm aperture and the valve arm end of the connector member includes knurls.

33. The system of claim 22, wherein the connector member lever arm end includes a lever arm end stop.

5 34. The system of claim 33, wherein the lever arm end stop includes a second shoulder defined by a lever arm end reduced-diameter portion.

35. The system of claim 33, wherein the lever arm defines a lever arm thickness and the second reduced-diameter portion defines a second axial length that is at
10 least as great as the lever arm thickness.

36. The system of claim 22, wherein the lever arm end of the connector member defines a first non-circular cross-section, and the lever arm aperture has a second non-circular cross-section corresponding to, and engageable with, the first cross-section
15 to inhibit relative rotation between the lever arm and the connector member.

37. The system of claim 36, wherein the valve arm end of the connector member defines a third cross-section, at least a portion of the third cross-section being non-circular and the valve arm aperture defines a fourth cross-section corresponding to,
20 and engageable with, the third cross-section to inhibit relative rotation between the valve arm and the connector member.

38. A method of manufacturing a valve-operating lever, the valve-operating lever including a connector member having an outside diameter, the method comprising:

providing a valve arm having a first aperture;

forming a first stop near a first end of the connector member;

5 positioning the valve arm adjacent the first stop such that at least part of the connector member is positioned within the first aperture; and

deforming the first end of the connector member to fixedly attach the valve arm to the connector member.

10 39. The method of claim 38, wherein the first aperture is substantially circular and the connector member is substantially cylindrical.

40. The method of claim 38, wherein the valve arm is formed using a stamping process.

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41. The method of claim 38, wherein the valve arm is substantially flat.

42. The method of claim 38, wherein the deforming step includes roller burnishing.

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43. The method of claim 38, wherein the deforming step includes forming a swage.

25 44. The method of claim 38, further comprising knurling at least one of an inner surface of the first aperture and an outer surface of the connector member.

45. The method of claim 38, further comprising providing a lever arm having a second aperture and a cam follower surface, and attaching the lever arm to the connector member.

5 46. The method of claim 45, further comprising forming a second stop at a second end of the connector member and positioning the lever arm adjacent the second stop of the connector member.

 47. The method of claim 46, further comprising deforming the second end of
10 the connector member to fixedly attach the lever arm to the connector member.

48. The method of claim 47, wherein the deforming the second end step includes roller burnishing.

15 49. The method of claim 47, wherein the deforming the second end step includes forming a swage.

 50. The method of claim 45, further comprising orienting the lever arm at an angle relative to the valve arm.

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 51. The method of claim 38, wherein the connector member includes a portion having a non-circular cross-section.

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52. The method of claim 51, further comprising inhibiting relative rotation between the connector member and the valve arm by forming a first aperture having a non-circular cross-section that engages the non-circular cross-section portion of the connector member.

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53. The method of claim 38, wherein the first end of the connector member includes a tubular portion having a hollow interior.

54. The method of claim 38, wherein the forming a stop step further
10 comprises forming a first shoulder in the connector member, the shoulder at least partially defined by a first reduced-diameter portion.

55. The method of claim 38, wherein the forming a stop step includes forming a second swage in the connector member.

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56. A method of assembling a valve-operating lever, the valve-operating lever including a valve arm having a first aperture, a lever arm having a second aperture, and a connector member, the method comprising:

- positioning the valve arm on a first end of the connector member such that a
5 portion of the connector member extends at least partially through the first aperture;
roller burnishing the first end of the connector member to deform the first end of
the connector member and fixedly attach the valve arm to the connector member;
positioning the lever arm on a second end of the connector member such that a
portion of the connector member extends at least partially through the second aperture;
10 and
roller burnishing the second end of the connector member to deform the second
end of the connector member and fixedly attach the lever arm to the connector member.

57. The method of claim 56, wherein the first aperture and the second aperture
15 are substantially circular and the connector member is substantially cylindrical.

58. The method of claim 56, further comprising knurling at least one of an
inner surface of the first aperture and an outer surface of the first end of the connector
member.

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59. The method of claim 58, further comprising knurling at least one of an
inner surface of the second aperture and an outer surface of the second end of the
connector member.

25 60. The method of claim 56, further comprising forming a connecting member
having a reduced diameter adjacent the first end.

61. The method of claim 60, further comprising forming a connecting member having a reduced diameter adjacent the second end.

62. The method of claim 56, further comprising providing a first reduced-
5 diameter portion having a non-circular region and engaging the non-circular region of the first reduced-diameter portion with a corresponding non-circular region of the first aperture to inhibit rotation of the valve arm relative to the connector member.

63. The method of claim 62, further comprising providing a second reduced-
10 diameter portion having a non-circular region and engaging the non-circular region of the second reduced-diameter portion with a corresponding non-circular region of the second aperture to inhibit rotation of the lever arm relative to the connector member.